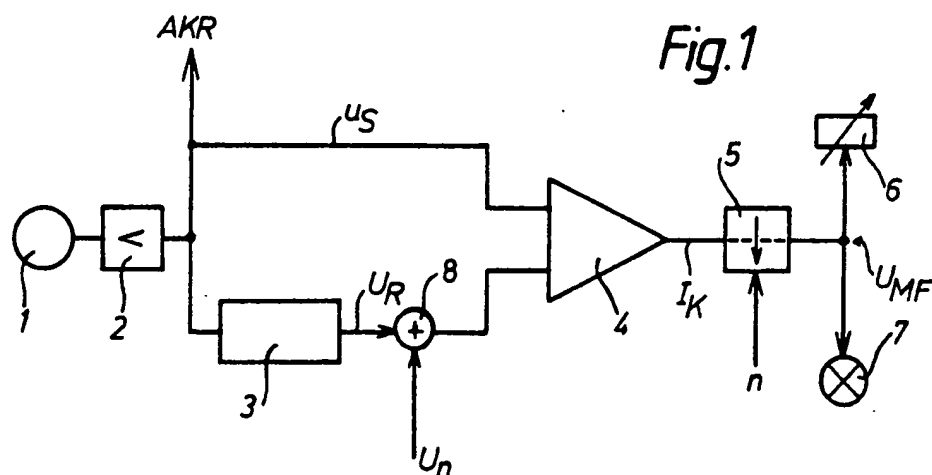
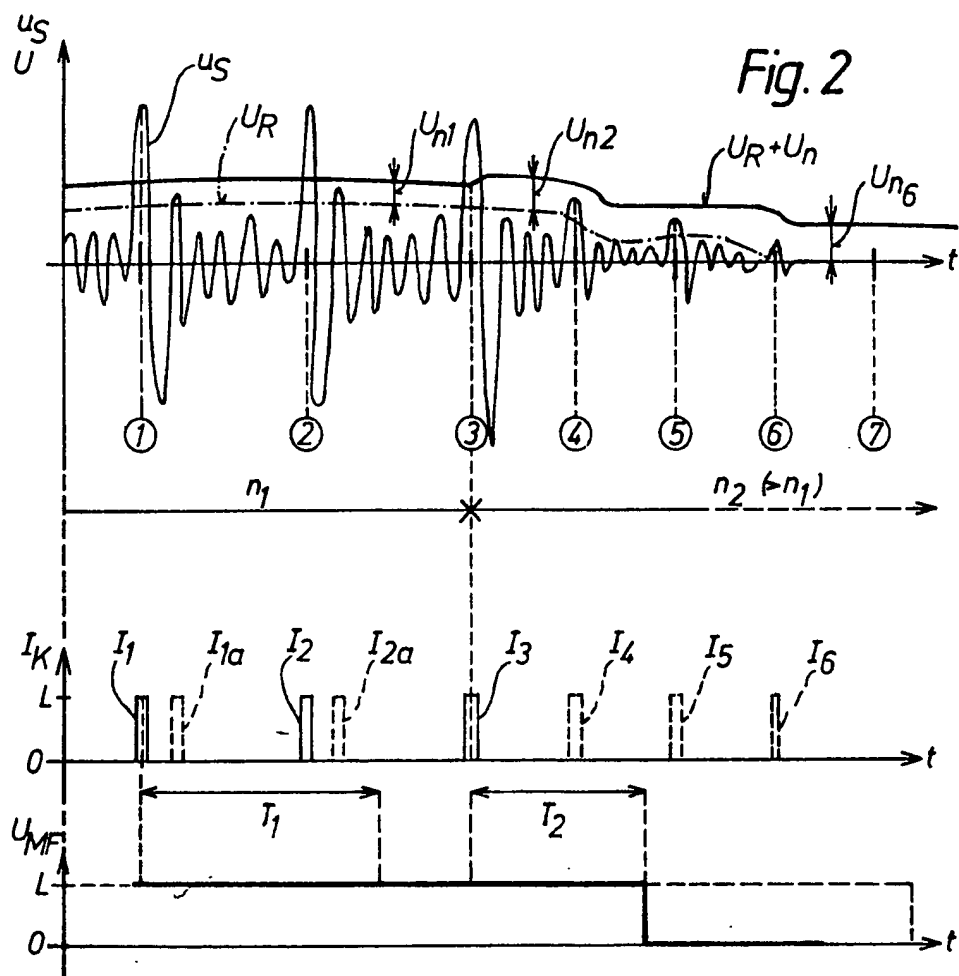
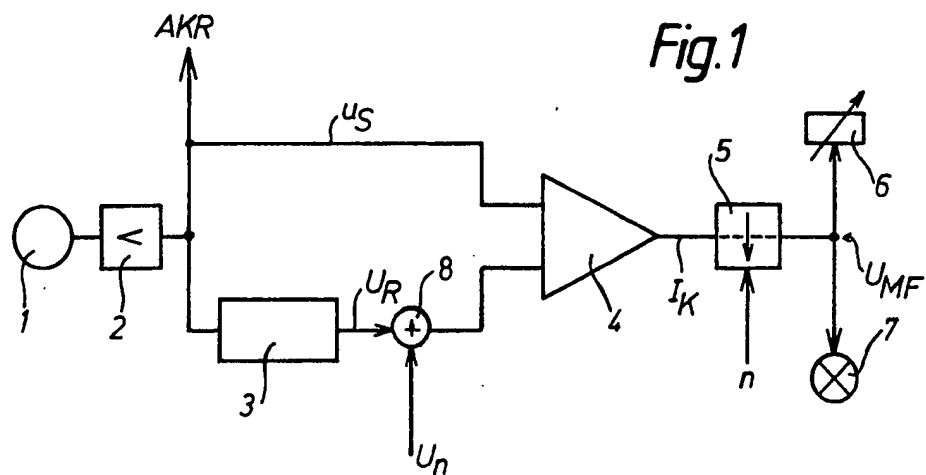


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*Fig. 1*



## SPECIFICATION

### A device for detecting the failure of a sensor

5 The invention relates to a device for detecting the failure of a sensor which is installed on a machine fitted with a rotatable component of components such as the failure of a knock sensor which is installed on an internal combustion engine, the  
10 output signal from this sensor being converted, in a reference circuit, to a rectified and smoothed reference signal which is compared, in a comparator, with a further quantity, a signal appearing at the output terminal of the comparator for as long as this  
15 further quantity exceeds the reference signal.

In many machines in which sensors are employed for regulating or controlling specific functions, the correct functioning of these sensors is of particular importance, since a failure of the sensor can lead to  
20 significant operational breakdowns or to the destruction of these machines. Thus, for example, the failure of a knock sensor which is installed on an internal combustion engine and the output signal of which is used for the automatic follow-up adjust-  
25 ment of the curve characterising the ignition timing, to conform with variations in the knock limit, can lead to rapid destruction of the internal combustion engine.

One device for detecting the failure of a sensor can  
30 be found in German Offenlegungsschrift 2,942,250. In the case of this device, tests are performed during test phases which lie between the combustion processes to determine whether the amplitude of the knock threshold lies within defined limits. A device  
35 of this type is insufficiently sensitive to react quickly enough in the event of a slow failure of the sensor.

The object of the invention is accordingly to provide a device which, in the event of a fault, is capable of reacting in a considerably more sensitive  
40 manner to a failure of the sensor, and which can emit an alarm signal as quickly as possible and/or adjust the machine which is to be monitored, so that consequential damage is minimised.

According to the invention there is provided a  
45 device for detecting the failure of a sensor which is installed on a machine fitted with at least one rotatable component the output signal from the sensor being converted, in a reference circuit, to a rectified and smoothed reference signal  $U_R$  which is  
50 compared, in a comparator, with the output signal ( $U_s$ ) from the sensor, the reference signal ( $U_R$ ) being diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals, of the output signal ( $U_s$ )  
55 from the sensor, a signal appearing at the output terminal of the comparator for as long as said peak values of the output signal ( $U_s$ ) from the sensor exceed the reference signal, a one-shot multivibrator being provided, which is adapted to be re-triggered  
60 by the output signal ( $I_K$ ) from the comparator and which has a delay time exceeding the time intervals of the output signal ( $U_s$ ) from the sensor, a control device and/or an alarm device being series connected, after the one shot multi-vibrator, and, in  
65 operation, emitting a control signal and/or an alarm

signal if the output signal ( $U_{MF}$ ) from the one-shot multivibrator vanishes.

According to the invention, a rectified and smoothed reference signal is formed from the  
70 sensor output signal, this signal exhibiting a curve shape which is a function of the load on the rotating machine parts and of the speed at which they are rotating, and in the case of internal combustion engines is, for example, a function of the variation of  
75 the compression pressure in a cylinder, of the structure-borne noise or of the ignition voltage, and this reference signal is diminished to the extent that, in each period, it is exceeded at least once by the peak value of the sensor output signal - the term  
80 "period" to be understood, both here and in the text which follows, as the mean time interval between the peak values of the sensor output signal at the rotation speed  $m$  at the time in question. These exceedance-events are detected in the comparator,  
85 the output signal from which is used for triggering a retriggerable one-shot multivibrator, so that when the sensor is functioning correctly, the multivibrator is always triggered and emits a continuous signal. If the sensor fails, the triggering pulses are also absent  
90 and, after expiry of the flip-flop delay, the multivibrator ceases to output a signal. The zero signal at the output terminal of the multivibrator is regarded as a failure signal and is used for emitting an alarm and/or an adjustment of the machine which is to be  
95 monitored.

Enhanced reliability with regard to faulty operation can be obtained if a speed-dependent signal is added to the reference signal, since this procedure permits not only the total failure to be detected, but  
100 also permits the detection of a marked reduction in the sensitivity of the sensor, which usually precedes a total failure.

Greater reliability with regard to faulty operation and more rapid detection of a failure can likewise be  
105 achieved if the delay time of the one-shot multivibrator which, if constant, must be longer than the period time at the slowest rotation speed, can likewise be varied as a function of the speed of the rotating machine part, so that it is, at all times, only  
110 somewhat longer than the period time at the speed prevailing at the moment in question, or of the function which is derived from this speed.

An embodiment of the invention will now be described by way of example with reference to the  
115 drawing in which:-

*Figure 1* shows a schematic circuit diagram of the device, and

*Figure 2* shows the variation, as a function of time, of the individual signals.

In *Figure 1*, the knock sensor 1 which is to be monitored is diagrammatically represented as a circuit, this sensor forming part of a so-called anti-knock control system, AKR, for an internal combustion engine. It can, for example, be a  
125 piezoelectric acceleration sensor of the type employed in control systems of this nature. Its output signal exhibits an alternating form which varies, in a periodic manner, between large-amplitude pulses and small-amplitude pulses, as a result of the fact  
130 that the machine parts are rotating or as a result of

the functions which are derived from these parts (in the case of internal combustion engines, the time-dependent variation of either the combustion pressure or the ignition voltage). After any amplification and filtering which may be necessary, performed in a circuit which is diagrammatically indicated as Box 2, this signal reaches, as the sensor output signal  $U_s$ , the anti-knock control system (AKR) which is not represented in the Figure, but is indicated by an arrow.

This sensor output signal  $U_s$  is supplied to a reference circuit 3, in which a rectified and smoothed reference signal  $U_R$  is derived and is diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals, of the normal, that is to say undisturbed, output signal  $U_s$  from the sensor. A rotation speed signal  $U_n$  which is a function of the speed at which the machine component is rotating is added, in the form of a direct-current voltage, to the reference signal  $U_R$  appearing at the output terminal of the reference circuit 3, this addition operation being performed in an analog adding circuit 8. The sum signal  $U_R + U_n$  is supplied to one of the input terminals of a comparator 4, the sensor output signal  $U_s$  being applied to its other input terminal. The comparator emits an output pulse  $I_K$  when the sensor output signal  $U_s$  rises above the sum signal  $U_R + U_n$ . These output pulses  $I_K$  are employed to trigger a retriggerable one-shot multivibrator 5, the duration of the output pulses from this multivibrator likewise being variable, as a function of the speed at which the machine part is rotating, and amounting, for example, to 1.5 times the period of the sensor output signal  $U_s$ . By this means, it is ensured that each of the pulses, which occur at least once per period, triggers the one-shot multivibrator, provided that its output pulse, triggered by the previous triggering pulse, is still present. As a result, if the sensor is intact, a constant digital output signal  $U_{MF}$  is produced, which is employed for triggering an alarm device 7 and a control device 6, for example for adjusting the ignition timing. The alarm is triggered whenever the output signal  $U_{MF}$  disappears.

The time-dependent variation of the individual signals is shown, in Figure 2, over a certain time. The sensor output signal  $U_s$  is represented as an alternating voltage signal with varying amplitudes, from which it is easy to recognise the "periodic variation" of the signal. The beginnings of the successive periods are respectively marked by the circled numbers 1 to 7. The periods 1 and 2 are assigned to a defined rotation speed  $n_1$ , while the following shorter periods are assigned to a rotation speed  $n_2$  which is higher by a factor of approximately 1.5. In the periods 1 to 3 the sensor signal can be said to be "normal", while in the periods 4 and 5 they are reduced, due to reduced sensitivity of the sensor, as a sign that a failure is beginning and, from period 6 onwards, they are no longer present, due to the fact that the sensor has failed.

The reference signal  $U_R$ , represented by a dash-dotted line, is formed from the sensor output signal  $U_s$ , for example by peak value rectification, and is

diminished to the extent that it is exceeded by at least one or two peaks of the sensor output signal. If this is the case, the comparator 4 emits output pulses  $I_K$ , which are represented in a second diagram drawn on a matching time scale. In the case of all the output pulses  $I_1$  to  $I_6$ , drawn with continuous lines and broken lines, the index figures being assigned to the correspondingly numbered period, the sensor output signal  $U_s$  exceeds the reference signal  $U_R$ . This also holds for the periods 4 and 5, during which the reference signal is, together with the reference signal is used as a threshold value, reduced sensor sensitivity is not detected as a fault. For this reason, a direct-current voltage which is a function of the rotation speed is added, as a speed signal  $U_n$ , to the reference signal  $U_R$ . In the upper diagram of Figure 2, the result  $U_R + U_n$  is represented as a continuous line, the value  $U_{n1}$  being assigned to the rotation speed  $n_1$  and the value  $U_{n2}$  being assigned to the rotation speed  $n_2$ . As a result, on the one hand, the duplicated pulses  $I_{1a}$  and  $I_{2a}$  are discarded, since they do not rise above the new threshold value  $U_R + U_n$ . For the same reason, the pulses  $I_4$  and  $I_5$  are discarded.  $I_6$  is discarded because even very small peaks in the sensor output signal which still rise above the reference signal, which is tending to zero, now no longer reach the value  $U_{n6}$ .

The difference can clearly be seen in the output signal  $U_{MF}$  from the one-shot multivibrator, this signal being plotted, against time, in the third diagram. The delay time  $T$  of the one-shot multivibrator, which is a function of the rotation speed, a duration of 1.5 times the period corresponding to the current rotation speed having been mentioned as an example, is marked  $T_1$  for the speed  $n_1$  and  $T_2$  for the speed  $n_2$ , and, triggered by the pulses  $I_1$  and  $I_3$  respectively, is plotted in each case as an arrow in the direction of the time axis.

In the case in which the reference signal  $U_R$  serves as the threshold value, the output signal  $U_{MF}$  does not terminate until the delay time of the one-shot multivibrator, triggered by the pulse  $I_6$ , has expired, in the seventh period, the reduction in the sensitivity of the sensor, occurring as a result of its becoming faulty, having been undetected, since only its complete failure is detected. This signal is represented by a broken line.

In the other case, in which the rotation speed signal  $U_n$  was added to the reference signal, the pulse  $I_3$ , at the output terminal of the comparator 4, is the last before the sensitivity of the sensor decreases to an extent such that the threshold value  $U_R + U_n$  can no longer be exceeded. The output signal  $U_{MF}$ , represented by the continuous line, terminates as soon as the delay time  $T_2$ , triggered by  $I_3$ , expires, in the fourth period, so that, in this case, it is already possible to initiate the alarm and/or the adjustment three periods earlier.

The failure detection device which has been described can be used in conjunction with all sensors which emit a "periodic signal" and is not, therefore, restricted to knock sensors for internal combustion engines.

## CLAIMS

1. A device for detecting the failure of a sensor which is installed on a machine fitted with at least one rotatable component the output signal from the sensor being converted, in a reference circuit, to a rectified and smoothed reference signal  $U_R$  which is compared, in a comparator, with the output signal ( $U_s$ ) from the sensor, the reference signal ( $U_R$ ) being diminished or amplified to the extent that it is continually exceeded by the peak values, appearing at regular time intervals of the output signal ( $U_s$ ) from the sensor, a signal appearing at the output terminal of the comparator for as long as said peak values of the output signal ( $U_s$ ) from the sensor exceed the reference signal, a one-shot multivibrator being provided, which is adapted to be retriggered by the output signal ( $I_K$ ) from the comparator and which has a delay time exceeding the time intervals of the output signal ( $U_s$ ) from the sensor, a control device and/or an alarm device being series connected, after the one shot multi-vibrator, and, in operation, emitting a control signal and/or an alarm signal if the output signal ( $U_{MF}$ ) from the one-shot multivibrator vanishes.
2. A device according to Claim 1, wherein an adding circuit is provided, in which, in operation, a speed signal ( $U_n$ ) is added to the reference signal ( $U_R$ ), this speed signal ( $U_n$ ) being a function of the rotational speed of the rotating machine component.
3. A device according to Claim 1 or 2, wherein the duration of the output pulse from the one-shot multivibrator is variable as a function of the rotational speed of the rotating machine component.
4. A device according to Claim 1, 2 or 3 wherein said sensor comprises a knock sensor installed in an internal combustion engine.
5. A device for detecting the failure of a sensor which is installed in a machine having at least one rotatable component, substantially as described herein with reference to, and as illustrated in the accompanying drawing.